Supplementary Information for:

Relocating croplands could drastically reduce the environmental impacts of global food production

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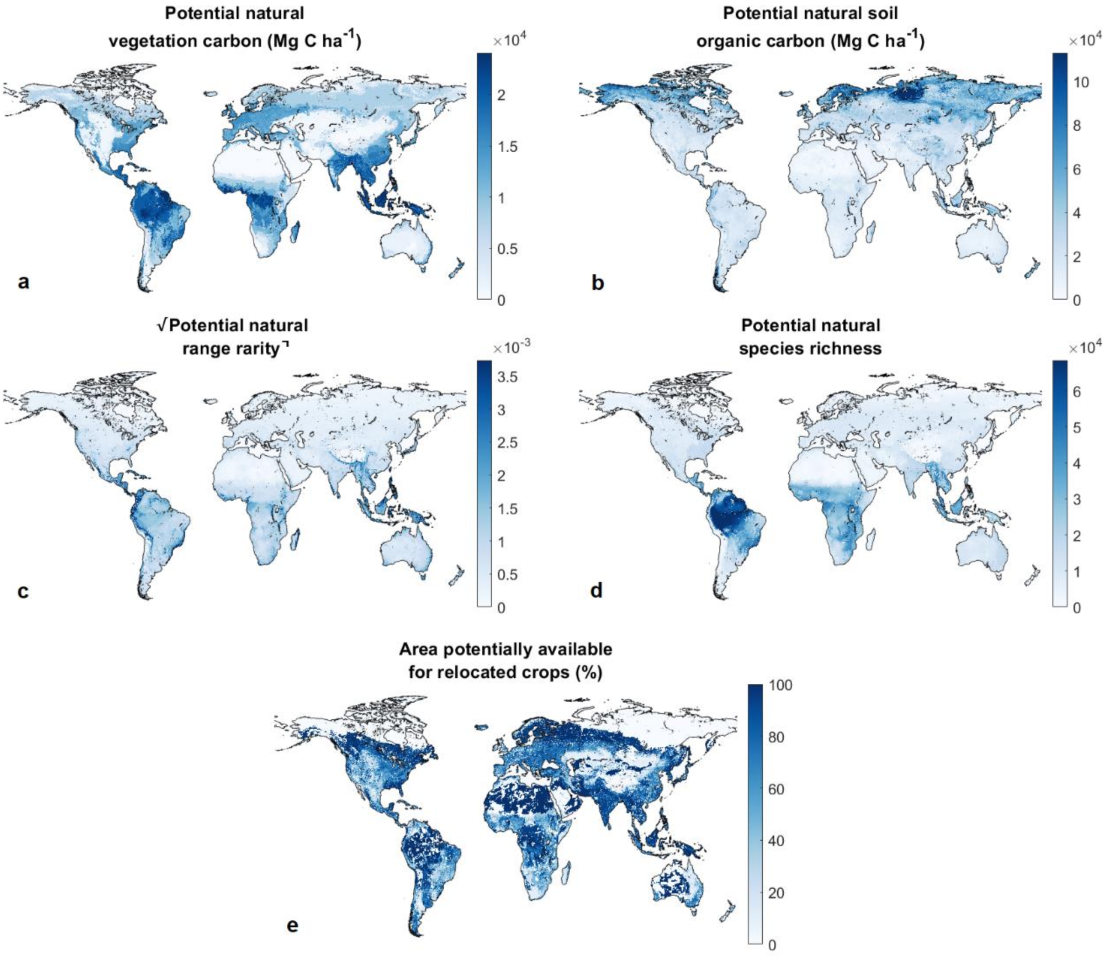
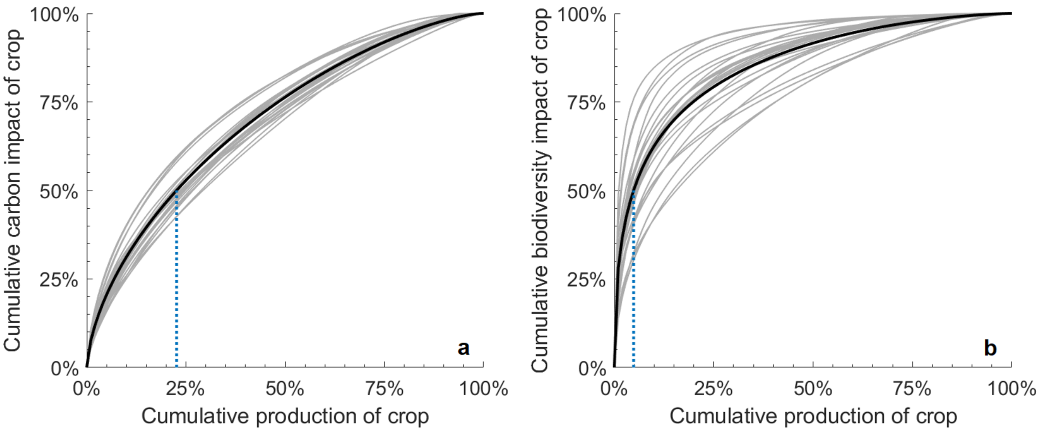
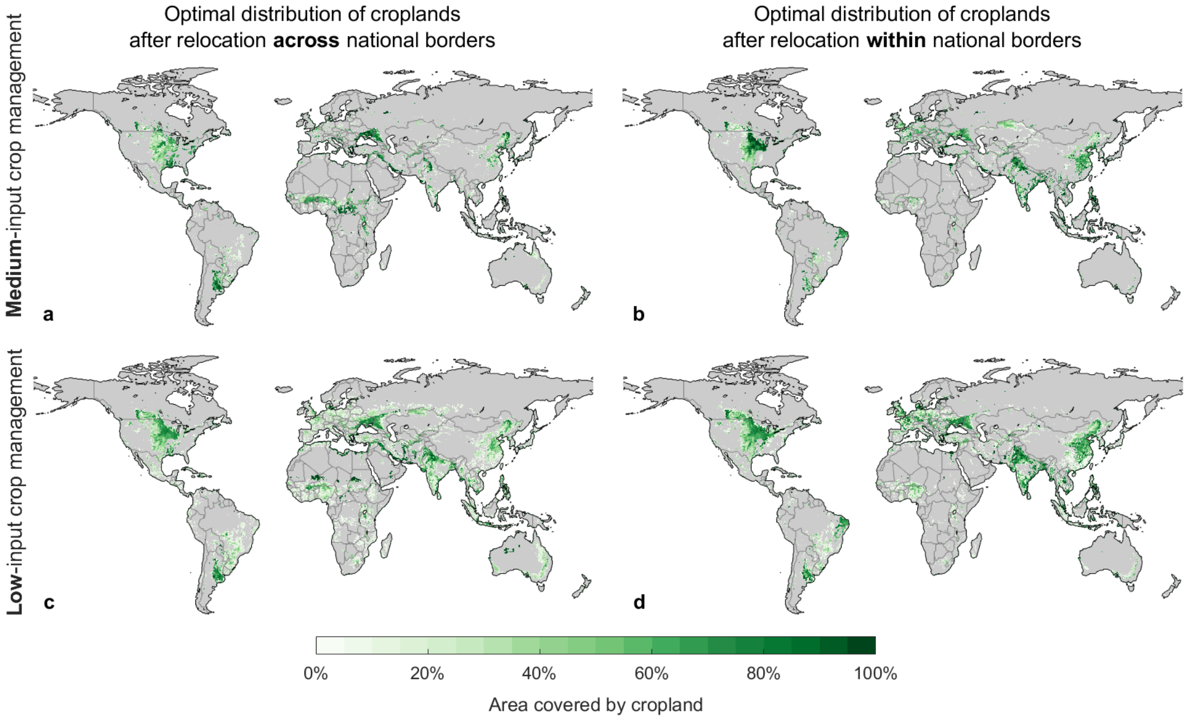
Supplementary Figures



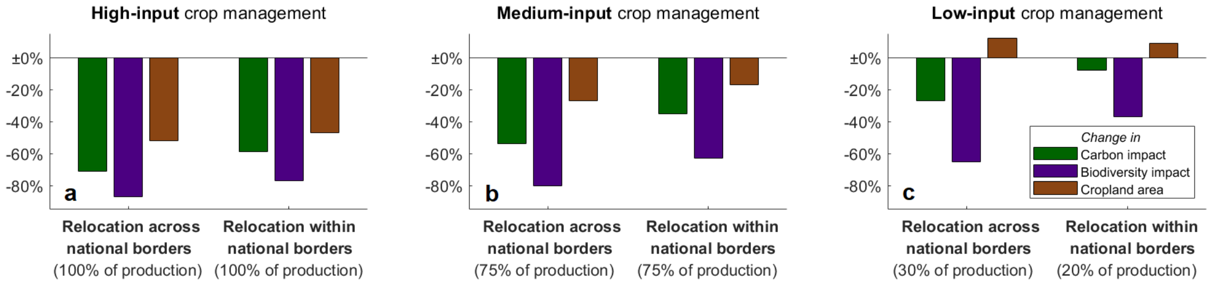
Supplementary Figure 1. Selected maps used in the optimisation framework. a Potential natural vegetation carbon, **b** potential natural soil organic carbon, **c** potential natural range rarity (square-rooted), **d** potential natural species richness, **e** land assumed potentially available for cropland.



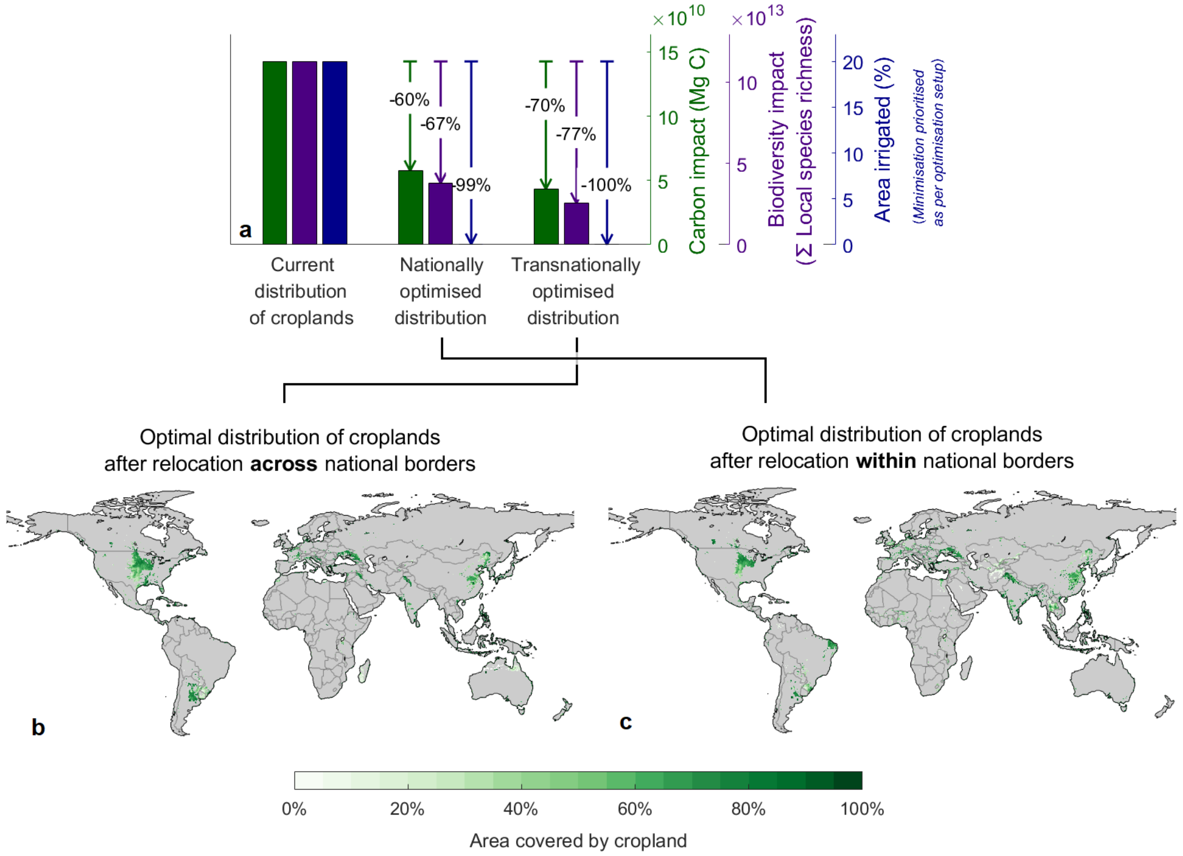
Supplementary Figure 2. Cumulative production and environmental impacts on current croplands. Each grey line is obtained by traversing the current growing locations of each crop in descending order of the ratio of local **a** carbon and **b** biodiversity impact to local production; black lines represent means across crops. The dotted blue lines represent the mean level of production on the least agro-environmentally efficient areas that causes half of a crop's total impact.



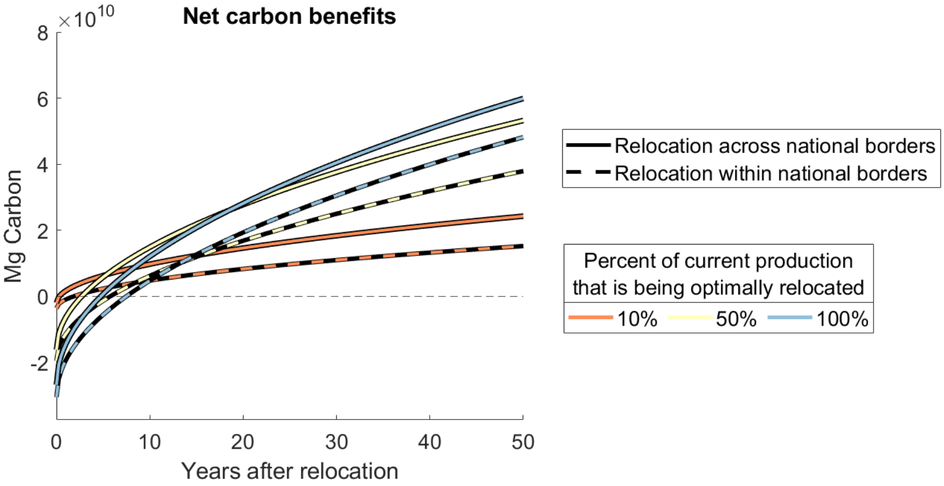
Supplementary Figure 3. Optimal distributions of global croplands assuming medium- and low-input management on newly established sites. Maps in **a**–**d** correspond to the scenarios represented by black markers in Fig. 3c–f, respectively.



Supplementary Figure 4. Environmental impact reductions compared to changes in global cropland area. Panels **a**–**c** correspond to the scenarios represented by black markers in Fig. 3.



Supplementary Figure 5. Optimal distributions of global croplands when measuring biodiversity in terms of species richness. Panels **a**–**c** are analogous to Fig. 1a,c,d but based on species richness as the measure of biodiversity.



Supplementary Figure 6. Estimated trajectories of the net carbon benefits of optimal crop relocation. In each scenario, the assumed relocation of production in year 0 to currently uncultivated areas causes instantaneous environmental impacts (given by the difference between natural and crop-specific carbon stocks in the vegetation and soil), which are gradually offset by the carbon recovery on the relevant abandoned areas (see the “Methods” section). Only the first 50 years are shown to illustrate the early timing of the break-even points. All scenarios are based on current climatic conditions, high-input management on new croplands, and an optimal carbon-biodiversity weighting (shown in Fig. 1c,d, and represented by black markers in Fig. 3a,b, for the scenarios of complete relocation).

Supplementary Notes

Supplementary Note 1. Carbon and biodiversity recovery on abandoned agricultural land. We briefly review empirical results on the recovery of carbon stocks and biodiversity on regenerating agriculturally degraded land. In both cases, recovery generally follows an asymptotic concave trajectory; the time required to reach pre-disturbance levels can therefore be difficult to pinpoint, as both slightly shorter or longer times correspond to similar recovery levels in the flat saturation stage of the recovery function. At small spatial scales, the regeneration of biodiversity and to a lesser degree carbon [107] can be highly context-specific. Depending on local factors, including land use history [26,108–111], habitat connectivity [109,112], other environmental factors [113], and whether or not restoration efforts actively support the recovery process [110,114,115], the regeneration in a specific location can take place at slower or faster speeds than would typically be the case in the broader ecoregion. At larger scales, above- and below-ground carbon stocks in forest biomes have been found to asymptotically reach pre-disturbance values within 50–100 years after land abandonment [25,27,28,30,103,105,106,110,116]. In grasslands, carbon stocks recover within a few decades [82,103]. Faunal species richness on regenerating degraded land tends to reach pre-disturbance levels on timescales of decades to a century [26,30,110,111,117–119]. Initial colonists may represent different species to those present before degradation occurred [29,109,118,119], but the proportion of old-growth species generally increases as secondary ecosystems age, thereby gradually replacing non-native species [29,30,118–121]. Biodiversity tends to regenerate faster in temperate than in tropical regions, and faster in grassland and shrubland biomes than in forests [26,108,110,111]. Whilst it has been argued that carbon and biodiversity recovery often occurs fastest under natural regeneration [114] (a result possibly due to methodological bias [115]), appropriate assisted restoration, including the direct reintroduction of species [122], is generally considered effective at accelerating the regeneration process [26,65,66,108–110,112,118,120,122,123].

Supplementary References

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